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PROGRESS REPORT

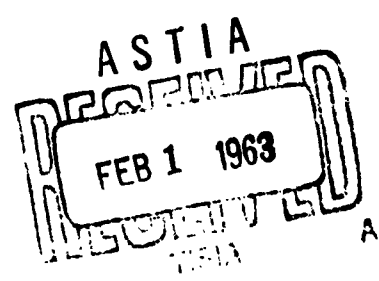
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University of Maryland

CODING AND USE OF INFORMATION IN PROBLEM SOLVING

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The report describes work completed and in progress on an investigation of problem solving as an information-processing system. Work is described on the areas of problem solving, encoding of perceptual information, and learning and storage of verbal materials.

NOTE: Copies of this report are filed with the Armed Services Technical Information Agency, Arlington Hall Station, Arlington 12, Virginia, and may be obtained from that agency by qualified investigators working under Government Contract.

Introduction

The purpose of the project is to study information processing aspects of problem solving and related problems of encoding and storage. Over the past year, work has been carried forward in three areas: problem solving; encoding of perceptual information; and learning and storage of verbal materials.

I. Problem Solving

A. Information processing in problem solving.

A final series of experiments on the information processing aspects of solving concept problems was completed. The experiments on the solving of concept problems have explored the following factors:

1. Example sign: whether the examples are positive or negative instances.
2. Concept size: the ratio of the number of relevant dimensions to the total number of example dimensions.
3. Series complexity: the presence of superfluous information.
4. Information order: the sequence of examples in series consisting of mixed positive and negative examples.
5. Storage load: the amount of information that has to be stored at the beginning of a problem.
6. Selection load: the amount of information required to sort the example dimensions into relevant and irrelevant.
7. Information rate: the rate at which new information is presented within the example series.

The findings make it possible to control the probability of solution of the concept problems. They also make it possible to specify in considerable detail the systematic operations carried out by the subjects in solving the problems. The operations consist of two distinct stages: 1) specification and storage of dimension values, 2) selection of relevant dimensions on the basis of example information. A general summary of a series of seven experiments carried out under the project is now in press (Psychological Monographs).

B. EEG concomitants of problem solving.

Experimental work was completed in a study of the relations between stages of problem solving and characteristics of the EEG output. An extended series of concept problems and control tasks were given to 12 sub-

jects while EEG recordings were made from both the occipital and parietal areas, to measure changes in the output of both alpha and kappa waves. The results show systematic and predictable changes in alpha for each stage of the problem solving. The results for kappa, however, show marked individual differences. These results contrast with the results of preceding work by Chapman, Armington and Bragdon, who, using somewhat simpler mental operations tasks, found that kappa showed marked regularity and predictability while alpha showed relatively weak effects. Experimental work has started to analyze the source of the differences in the two types of task.

II. Encoding in Perception

The work on problem solving underlined the importance of the subjects' encoding mechanisms in the storage and processing of information. In order to study the encoding mechanisms in the framework of relatively simple tasks, a series of studies was carried out on the role of encoding in perceptual recall. The main outcome of these studies is a radical simplification of the problem of form perception.

A. Experiments with systematically generated stimuli of the type used in information theory studies.

The first series of experiments was carried out to analyze the determinants of the difficulty of perceptual recall of a systematically varied set of stimuli. The stimuli were arrays of eight shapes that were each either black or white. First, the accuracy with which subjects could reproduce these arrays under $\frac{1}{2}$ sec. exposure was determined. Then, another method involving discrimination between arrays was used to determine the difficulty of the individual stimuli. The discrimination method yielded a similar ranking of accuracy scores. This indicated that the accuracy scores obtained with the reproduction method were not a function of the particular method used. The accuracy scores were then subjected to various types of analysis. An analysis based on information measure showed only partial success in accounting for the difficulty of individual stimuli. Analysis based on gestalt theory was also found to be unsatisfactory. Another type of analysis was constructed, based on the hypothesis that the subjects' perceptual processing includes a covert verbal encoding and that the length of the verbal code determines the difficulty of the stimulus for perceptual tasks. This was labelled the verbal loop hypothesis. Empirically-derived measures based on this hypothesis were shown to account for a major part of the variance in stimulus difficulty. The relevance of the assumption and the findings to the general problem of perceptual organization and encoding is discussed. The verbal loop hypothesis is presented as an alternative to gestalt and information theory analyses of organization. A paper describing this work is currently in press (J. verb. learn. & verb. Behav.).

B. Experiments with Binary Numbers

Further experiments were carried out to test the generality of the verbal loop hypothesis--the hypothesis that the subject's perceptual processing includes a covert verbal encoding and that the length of the verbal code determines the difficulty of the stimulus. In one experiment, a relation was demonstrated between verbal code length and the accuracy for binary numbers over the range from 0 to 11111111 (decimal 255). Since these numbers varied in length from one to eight digits, an alternative explanation based on the physical length of the stimulus was considered. Predictions on the basis of number of digits were almost as effective as predictions on the basis of verbalization length. In another experiment, it was demonstrated by converting all the binary numbers into eight digit form (e.g., 0 becomes 00000000) that the relation between verbal code length and accuracy is the more general one. The relation between length of the verbal code and accuracy remains invariant even when the effect of the physical length of the stimulus is eliminated. A third experiment replicated the results of the preceding experiment and permitted the evaluation of the role of context and sequence effects in determining the relation between verbal encoding and accuracy. The effect of these other factors was found negligible.

C. Experiments with Conventional Figures

The final set of experiments carried the work on the verbal loop hypothesis to conventional figures of the type used in the studies of gestalt factors in perception. Procedures similar to those used in work described above were used. In one experiment, a relation was demonstrated between verbal code length and the difficulty of such conventional figures. In another experiment, a relation was demonstrated between the verbal code length and the judged complexity of these figures. This last set of experiments completes the demonstration of the generality of the verbal loop hypothesis. The conventional figures that were used in these experiments have proved intractable to analysis by either information theory or gestalt theory. Information theory cannot be applied directly to such stimuli. It has been applied instead to simplified stimuli that bear some rational relation to such stimuli. Gestalt theory has never been applied systematically to figures of this type.

III. Learning and Storage of Verbal Materials

Work has continued on the analysis of serial position effects in both rote learning and free recall of verbal materials. The general hypothesis motivating the work is that serial position effects can be used as a lever to discover the inner structure of storage mechanisms in human subjects.

A. Serial position effects in rote learning.

An experiment was carried out to evaluate the hypothesis that serial position effects in verbal learning are based on facilitative

effects. This type of explanation is opposed to the classical explanations in terms of inhibitory or interference effects, e.g., the Hull-Lepley hypothesis. One hundred and forty college students were given serial learning tasks in which particular items were facilitated by pretraining. The results of this and earlier experiments indicated that neither the facilitative nor the inhibitory explanations are correct. The results of the experiments indicate rather strongly that attempts to handle the serial position effect as a result of the interaction of items in the list is incorrect. It seems now that the serial position effect is more likely to be a result of a strategy that the subject adopts in dealing with the list. One version of this view is that the subject generates the serial position effect on the basis of instructions that he gives himself at the start of the learning task concerning the structure of the list.

Following up this idea, another experiment was carried out in which an attempt was made to bring these hypothesized instructions under experimental control by having the experimenter indicate verbally the beginning and middle of the list. A group of 60 subjects was run under the following experimental conditions. For half the subjects, the verbal instruction agreed with the physical appearance of the list (i.e., the experimenter identified the first item that appeared on the memory drum as the start of the list). For the other half of the subjects, it was in opposition (i.e., the experimenter told the subject that the first item that appeared was the middle of the list). The results indicate that verbalization plays a major role in generating the serial position effect and that the explanation of this effect in rote learning must be sought in terms of self-instruction by the subject.

B. Serial position in free recall.

Previous work on the free recall of verbal material in which presentation rate and amount of delay before recall were systematically varied has indicated that the subject makes use of two types of storage--short term storage and long term storage. The nature of these two storage mechanisms was examined further in an experiment in which presentation rate and number of repetitions of each item in the recall list was systematically varied. Twelve groups of subjects with 20 subjects in each group were tested, each on a series of eight 20-word lists. The data of this experiment are currently being analyzed.

PROFESSIONAL ACTIVITIES

The following papers were presented to professional organizations:

- Glanzer, M., & Clark, W.H. Mechanics of concept-work: Information rate. Eastern Psychological Association, Atlantic City, N.J., April 27, 1962.
- Glanzer, M. Language structure: Experimental and developmental aspects. The University of Michigan, Speech Clinic, Ann Arbor, Michigan, August 3, 1962.
- Glanzer, M., Chapman, R.M., Clark, W.H., & Bragdon, H.R. Changes in two EEG rhythms during a problem-solving task. Psychonomics Society, Washington University, St. Louis, Mo., August 30, 1962.
- Glanzer, M. Systematic operations in solving concept problems. Symposium on concept attainment, American Psychological Association, St. Louis, Mo., September 3, 1962.

PUBLICATIONS

- Glanzer, M., & Peters, S.C. Re-examination of the serial position effect. J. exp. Psychol., 1962, 64, 258-266.
- Glanzer, M. Grammatical category: A rote learning and word association analysis. J. verb. learn. & verb. Behav., 1962, 1, 31-41.
- Glanzer, M., & Clark, W.H. Accuracy of perceptual recall: An analysis of organization. J. verb. learn. & verb. Behav., in press.
- Glanzer, M. Toward a psychology of language structure. J. speech & hearing. Res., 1962, 5, 303-314.
- Glanzer, M., Huttenlocher, Janellen, & Clark, W.H. Systematic operations in solving concept problems: A parametric study of a class of problems. Psychological Monographs, in press.
- Glanzer, M. Experimental study of team training and team functioning. In Robert Glaser (Ed.), Training Research and Education. Univ. of Pittsburgh Press, 1962. Chap. 13, pp. 379-407.